

Metrology for Freeform Optics (MFO)

Completed Technology Project (2017 - 2019)



Project Introduction

Science requirements for optical instrumentation are requiring larger fields of view and faster f-numbers to complete their objectives. Additionally, opportunities for CubeSat and SmallSat missions are growing as they are seen as a low-cost alternative to perform science for NASA. These demands for fast, wide-field, and small-sized instrument payloads are challenging for traditional optical design forms due to the severe packaging constraints. Optical surfaces with "freeform" shapes, however, enable additional degrees of freedom to help reduce volume and even eliminate surfaces from the more traditional design options. Recent GSFC IRADs have investigated the capability of industry to manufacture these surfaces, but, as a final, capstone to this progress, funding is needed to improve the in-house metrology efforts to verify the components, and to develop new and better methods for assembly and alignment of this sensitive optical systems. This work culminates the series of other GSFC IRAD work in the design and fabrication of freeform optics. Furthermore, this effort is fully in line with improving GSFC's capability for testing of other, more traditional aspheric surfaces to reduce costs and keep GSFC at the state of the art and competitive.

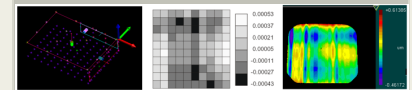
The objective of this proposed work is to mature the technology to reduce risk in implementing freeforms into optical systems and to improve metrology for aspheres in general. This effort will focus on "metrology" of optical surfaces with freeform prescriptions.

In this work, we will characterize existing optical components using CMM metrology and interferometry for both traditional and freeform optics. We will explore and characterize sources of systematic and random error in the two metrology methods. We will calibrate alignment fiducials using the CMM and then align a simple optical system with the fiducial-based approach, afterward verifying performance with interferometry. A detailed comparison of methods and thorough characterization of uncertainties from these methods has hitherto not been performed to the nm-level needed for visible and UV missions.

This will improve GSFC's capability to perform acceptance testing when vendors supply the Government with freeform optics. This acceptance testing will consist of surface error checks using the CMM and fiducial calibration checks. This will establish GSFC's capability to align freeform optical systems using this fiducial-based approach. This work will identify and document new technologies and pursue collaborations with industry through the New Opportunities Office, as appropriate.

Anticipated Benefits

In the end, this work will result in an improved knowledge base and state of the art for freeform mirror fabrication and testing. Benefits include:



Images showing surface data from freeform optics from measurement methods that will be further developed by this effort.

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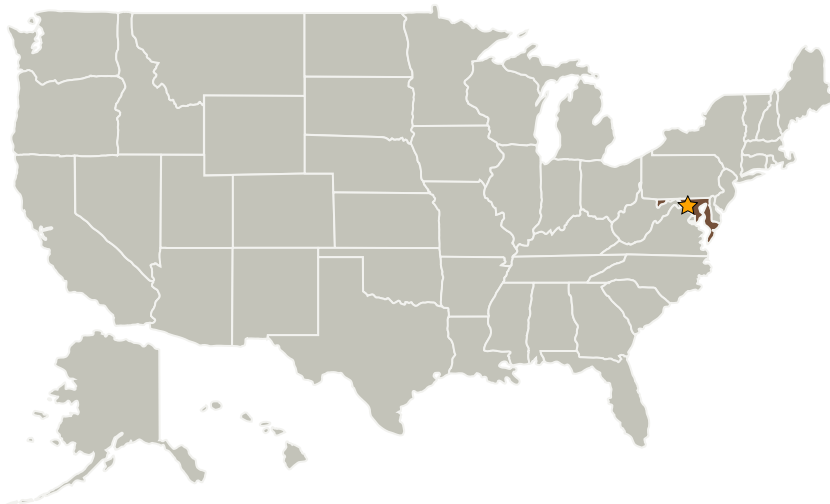
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- Improving GSFC's and industry's ability to perform testing for freeform surfaces using optical CMM and interferometry.
- Improving the ability to align freeform and other aspheric systems for future flight applications to the tolerances typical of future visible and near-UV missions.
- Reducing the cost of freeform optics by spreading this capability to industry.
- Improving optical metrology capability for small-package instrumentation, which will enable future CubeSat and SmallSat missions, and better position partners for future work for NASA.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Goddard Space Flight Center (GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations

Maryland

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Independent Research & Development: GSFC IRAD

Project Management

Program Manager:

Peter M Hughes

Project Managers:

Terence A Doiron

Michael A Johnson

Principal Investigator:

Raymond G Ohl

Co-Investigators:

Joseph M Howard

Philip Dabney

Corina M Koca

Manal A Khreishi

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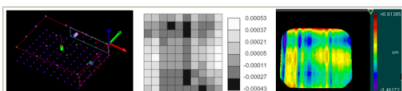


Project Transitions

**October 2017:** Project Start**September 2019:** Closed out

Closeout Summary: Future science from orbit requires optical instruments with larger fields of view and faster f-numbers to complete their objectives. The use of "freeform" optics can improve the performance of optical systems and significantly reduce the package size, enabling small, space-based optical instrumentation for NASA science missions ranging from Earth sciences to planetary applications. Additionally, opportunities for CubeSat and SmallSat missions are growing as they are seen as a low-cost alternative to perform science for NASA. These demands for fast, wide-field, and small-sized instrument payloads are challenging for traditional optical design forms due to the severe packaging constraints. Optical surfaces with "freeform" shapes, however, enable additional degrees of freedom to help reduce volume and even eliminate surfaces from the more traditional design options. For this project, engineers will test freeform optics and other aspheres to improve the use of metrology equipment for these unusual prescriptions. In addition, they will build a telescope system using freeform optics. Error budgets, procedures, reports, and software will be produced that will make working with freeform surfaces easier.

Images

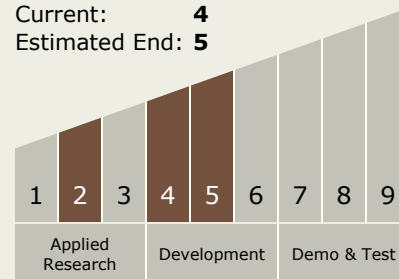
**Metrology for freeform optics**

Images showing surface data from freeform optics from measurement methods that will be further developed by this effort.

(<https://techport.nasa.gov/image/34349>)

Technology Maturity (TRL)

Start: **2**
Current: **4**
Estimated End: **5**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
 - └ TX12.4 Manufacturing
 - └ TX12.4.3 Electronics and Optics Manufacturing Process

Target Destinations

Earth, Others Inside the Solar System, Outside the Solar System

Supported Mission

Type

Projected Mission (Pull)